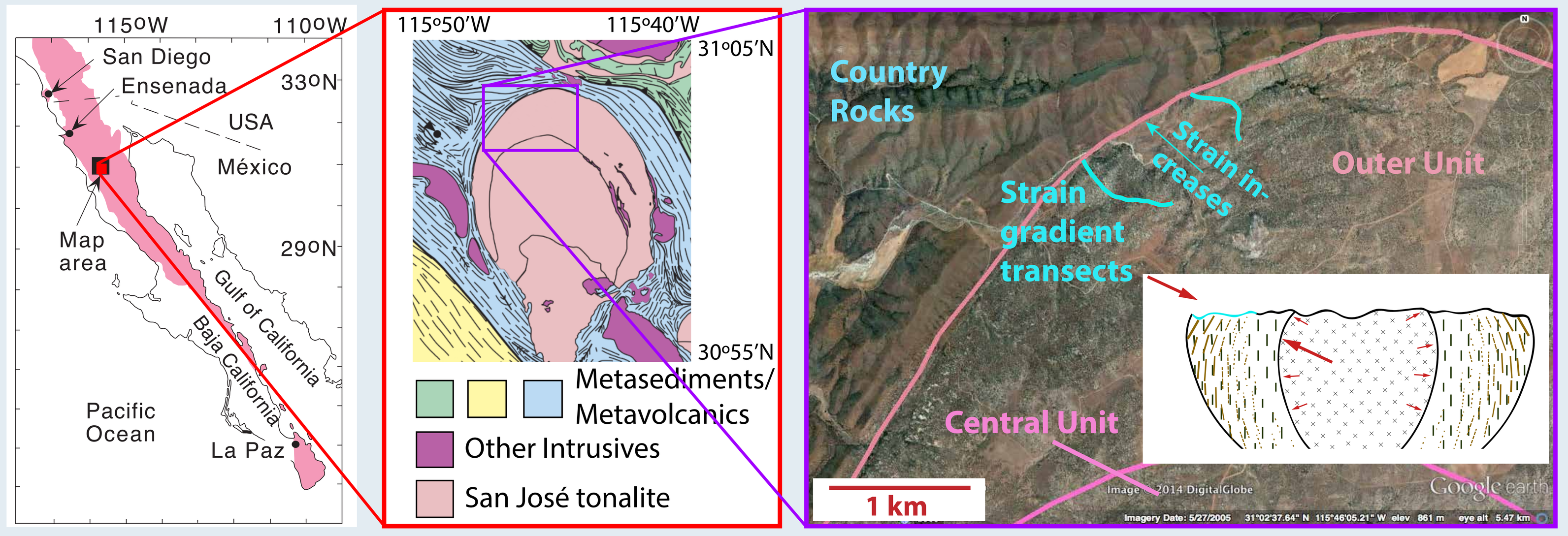
Deformation-Enhanced Element Mobility in Feldspar: A Strain Speedometer?

Naomi Barshi*, Christie Rowe, and Vincent van Hinsberg
Department of Earth and Planetary Sciences, McGill University, Montréal, QC, Canada
*naomi.barshi@mail.mcgill.ca

Hypotheses

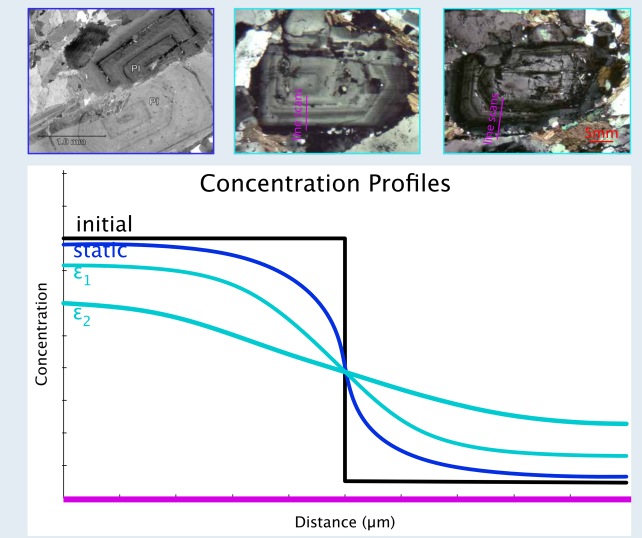
1. Deformation enhances diffusion in minerals.[1]
2. This enhancement varies systematically with strain for a variety of elements.
3. The differences in concentration contrasts measured in zoned plagioclase across a strain gradient can be compared to infer a duration of deformation and estimate strain rate.

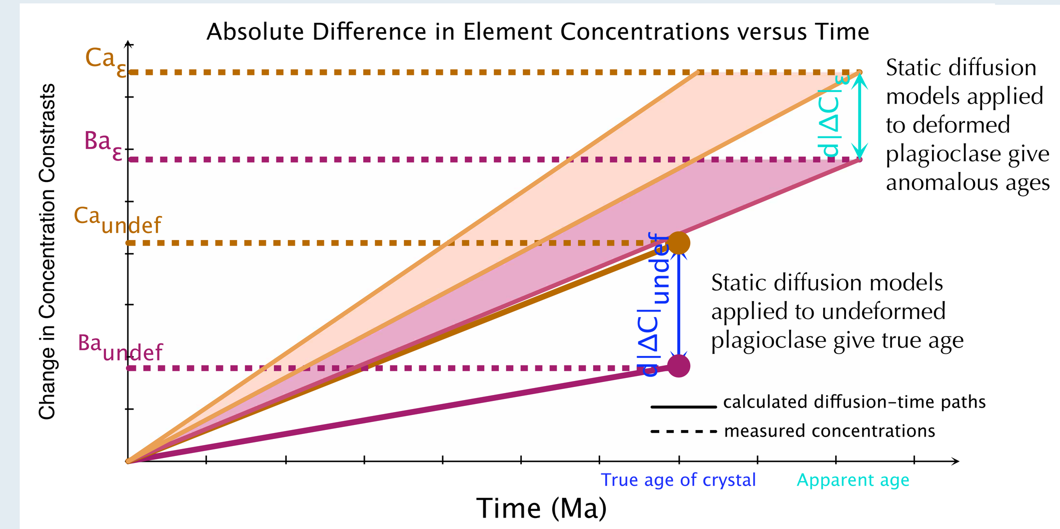
Geologic Setting



Oriented samples were taken along two strain gradients in the outer and oldest unit of the Lower Cretaceous San José pluton, Peninsular Ranges batholith. This tonalite pluton experienced solid-state deformation during subsequent pluton emplacement[2]. Plagioclase-dominated rheology and simple deformation history make it an ideal location to investigate element mobility in feldspar. (Overview maps modified from Johnson *et al.*[2] and satellite image Digital Globe/GoogleEarth 2014.)

Approach

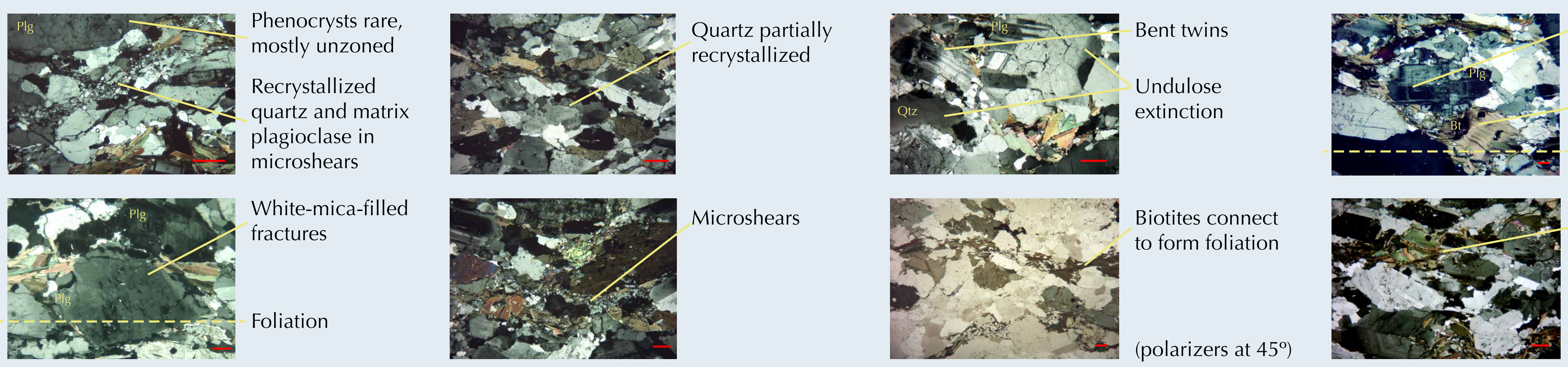




I will measure element concentrations across zoning at each strain increment, illustrated here for undeformed (dark blue[3]) and intermediate and high strain (light blue). When elements with different diffusion coefficients are compared (for example Ca and Ba), their diffusion paths can be modeled to calculate a duration of diffusion equivalent to the age of the crystal. If diffusion enhances element mobility, then deformed crystals will appear older. We interpret this difference as the duration of deformation.

1. Describe and sample a strain gradient (done)
2. Establish a quantitative strain scale against which to measure element concentrations (current work)
3. Measure concentrations of the same elements in zoned feldspars across a strain gradient (next step)
4. Measure concentrations of different elements at each strain increment constrain the duration of enhanced diffusion, which we interpret as the duration of deformation (next step)

Strain Gradient



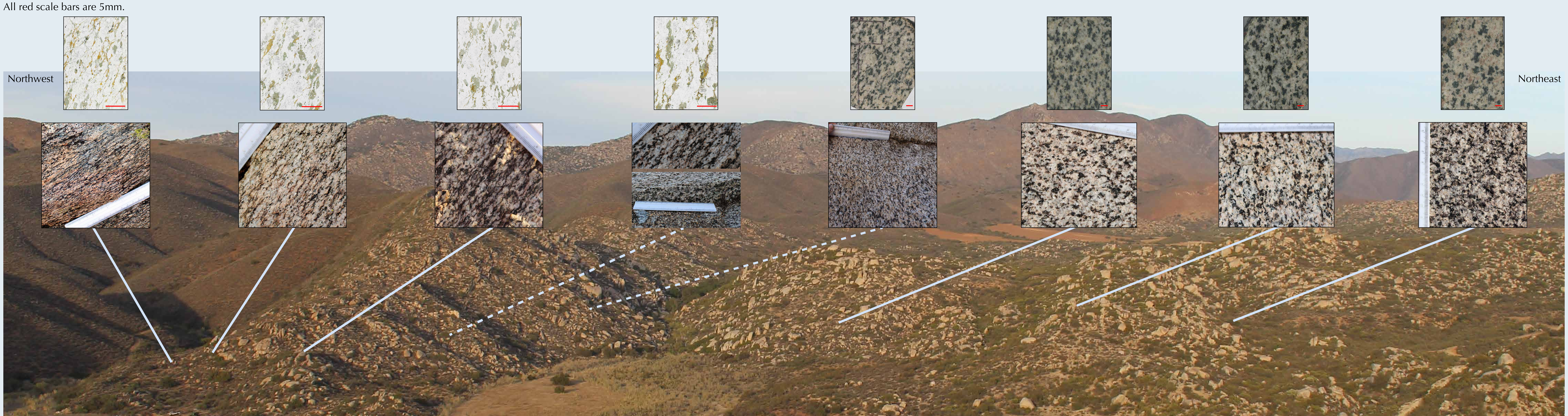
All red scale bars are 5mm.

Trends toward edge of pluton

- Grain size of all minerals decreases
- Plagioclase and quartz in deformed samples have undulose extinction
- Plagioclase phenocrysts lose their zonation and decrease in size and abundance
- Biotite increasingly but incompletely overprints hornblende and associated magmatic fabric
- Plagioclase develops a strong shape-preferred orientation

Remaining Challenges

- How do I translate this qualitative strain gradient into a quantitative strain metric for feldspar at the mineral scale?
- What are the best strain markers to use?
- Plagioclase dominates the San José tonalite, but how much bulk strain does it accomodate (represent)?



View of the north-eastern transect taken from the south-eastern transect illustrated in Geologic Setting. Cars in lower left-hand corner for scale.

Dotted lines indicate photos were taken on equivalent outcrops on parallel transect.

Field photos oriented to show strike and thin section and sample scans oriented to show dip of fabric and foliation (cuts are foliation-perpendicular, lineation-parallel when present).

References
1. Demonstrated in metals, e.g. Cohen, M., *Bulletin of the Japan Institute of Metals* **9**, 271–278 (1970); and in tourmaline by Büttner, S. H., *Mineralogical Magazine* **69**, 471–490 (2005).
2. Johnson, S. E., Tate, M. C., & Fanning, C. M., *Geology* **27**, 743–746 (1999). 3. Vernon, R. H., Johnson, S. E. & Melis, E. A., *Journal of Structural Geology* **26**, 1867–1884 (2004).

Acknowledgements
Thanks to Field Rheology and FlexPet groups and field assistant Matt Paulson. This project is funded by NSERC (van Hinsberg and Rowe), FQRNT (Rowe), GREAT (Barshi), and a Robert Wares Fellowship (Rowe).

*naomi.barshi@mail.mcgill.ca
FDA 238, 3450 University Street
Montréal, QC, H3A 0E8, CANADA